Can Regional Models Capture Precipitation and Temperature Extremes?

Performance of RSM in a 5-Decade Reanalysis

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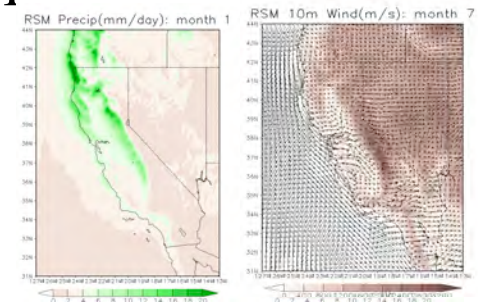
California Heat Waves: 2006 and the climate record

Motivations

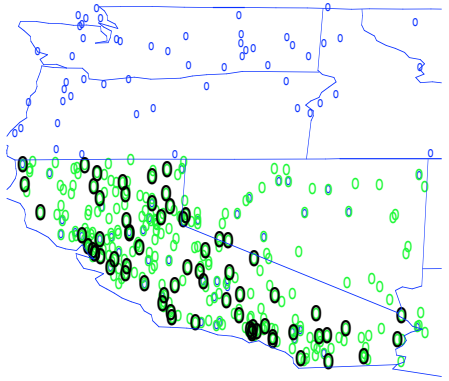
- Assess performance of regional model(ing) over California's complex terrain
- Learn a little about California climate in the process

Model Data: California Regional Downscaling (CaRD10)

- Scripps Experimental Climate Prediction Center Hydrostatic Global to Regional Spectral Model (G-RSM).
  - ➔ **Highest possible spatial resolution of ~10km.**
- NCEP/NCAR Global Reanalysis as large-scale forcing.
  - ➔ **Only analysis that goes back to 1948.**
- Apply **Scale Selective Bias Correction** technique to preserve the large-scale forcing field within the domain.
- **No other observations**, except SST, are used.
  - Does not incorporate change in land use.
  - Responses due to changes in large scale atmospheric circulation and SST.
- Hourly output aggregated to daily in this analysis



Observational Data



- California and Nevada daily Precipitation, Tmax and Tmin @ 286 stations: 1948 – 2005
- California Tmax&Tmin @ 69 stations: May – July 2006 (thanks to Laura Edwards, DRI)

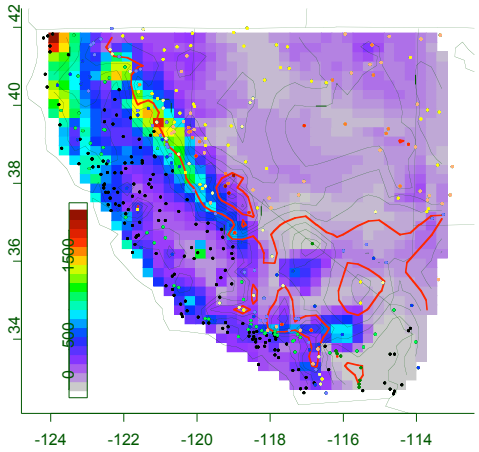
- Drizzle below observational limit (0.25mm) has been removed from model data

PRECIPITATION OUTLINE

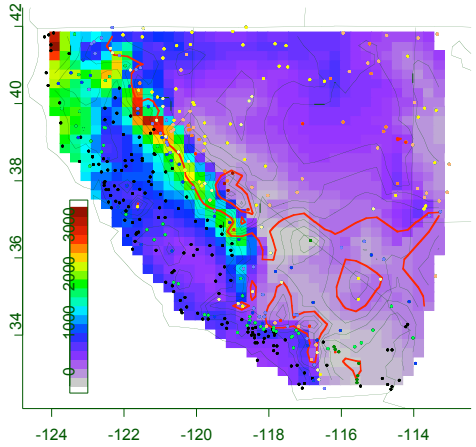
- Simple daily precipitation statistics: diagnostics in observation & model
  - Water year total
  - Daily frequency
  - Average daily intensity
  - Contribution of heavy precipitation to total
  - Year-to-year model-observations correspondence
  - Day-to-day correspondence
  - Model frequency correction

Mean Water Year (October – May) Precipitation

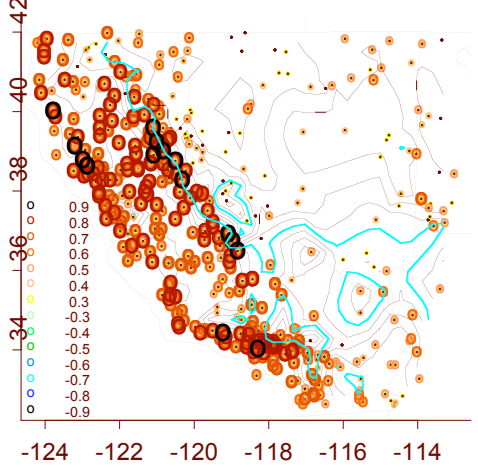
Mean Observed Water Year Precipitation



Mean Modeled Water Year Precipitation



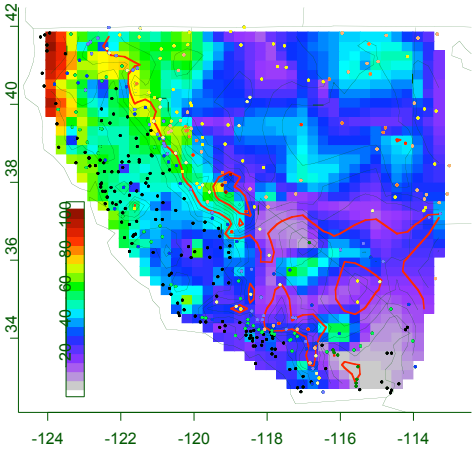
Correlation of Modeled and Observed Total



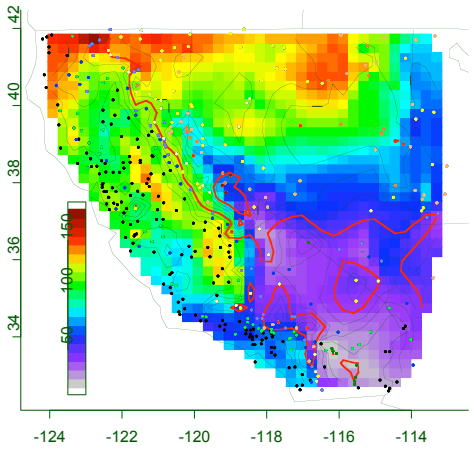
Not bad, but annual precipitation amount is overestimated and there is good interannual correspondence only on windward topography

Precipitation Frequency (days)

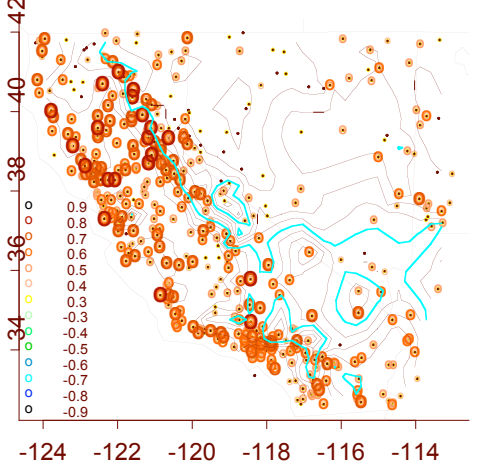
Observed Precipitation Frequency



Modeled Precipitation Frequency



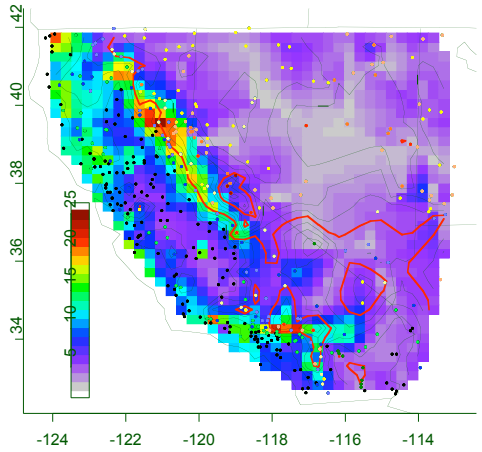
Correlation of Modeled and Observed Freq



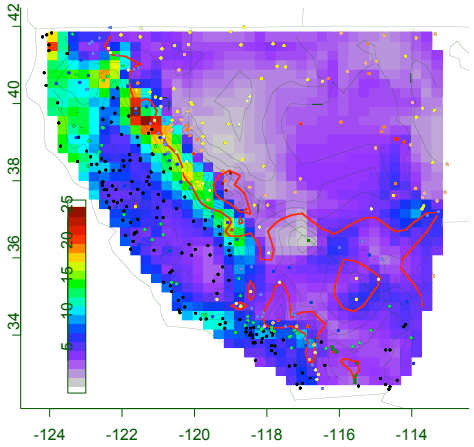
Frequency is overestimated everywhere, especially over the Central Valley and the northern high desert

Average Precipitation Intensity (mm)

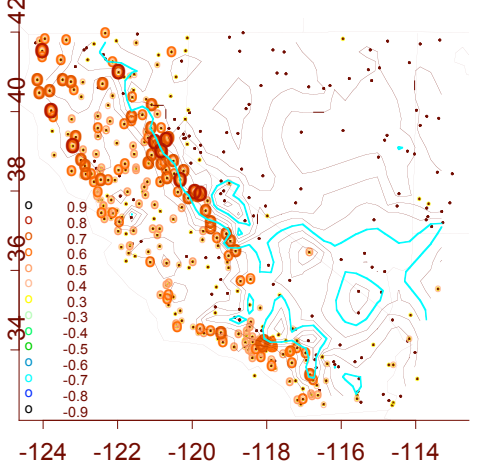
Observed Average Intensity (Prate)



Modeled Average Intensity



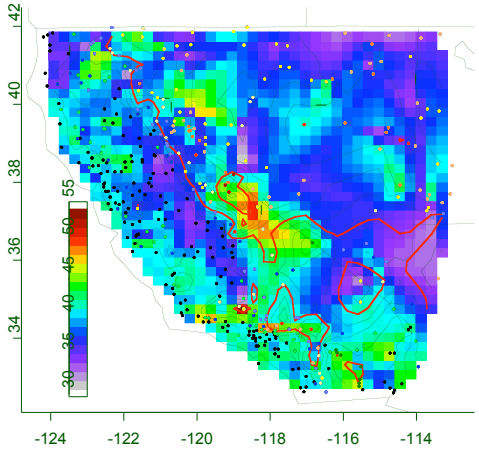
Correlation of Modeled and Observed Int.



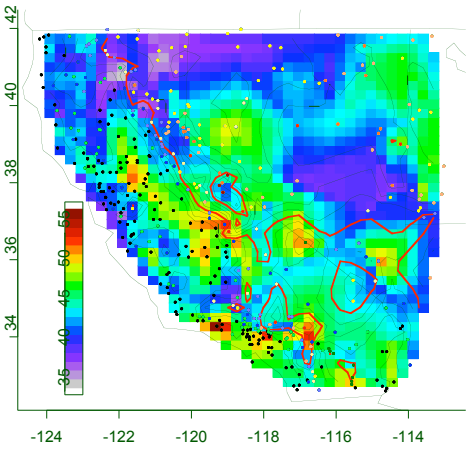
Average daily intensity is very well reproduced, but *moderate* interannual correspondence exists only on windward slopes of major topography

Contribution of heavy (P90) daily precipitation to water-year total

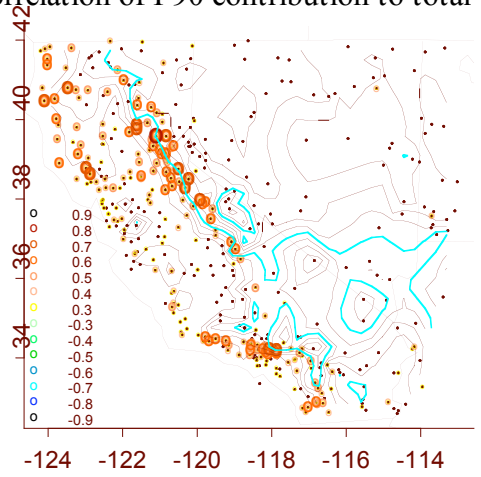
Observed P90 contribution to total



Modeled P90 contribution to total



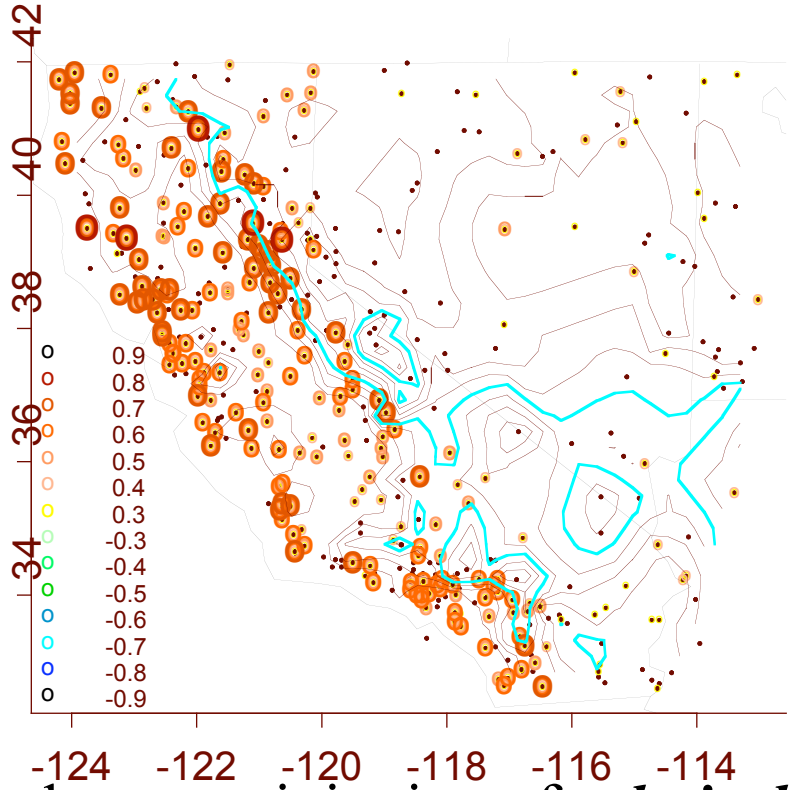
Correlation of P90 contribution to total



Severely overestimated in the Central Valley.

Almost no interannual correspondence away from windward topography, where correspondence is weak.

Water year average daily Spearman's correlation coefficient – the daily correspondence of model with observations. Ranking the daily amounts removes the effect of biases in the modeled climatology, accept for the bias in frequency, of course.

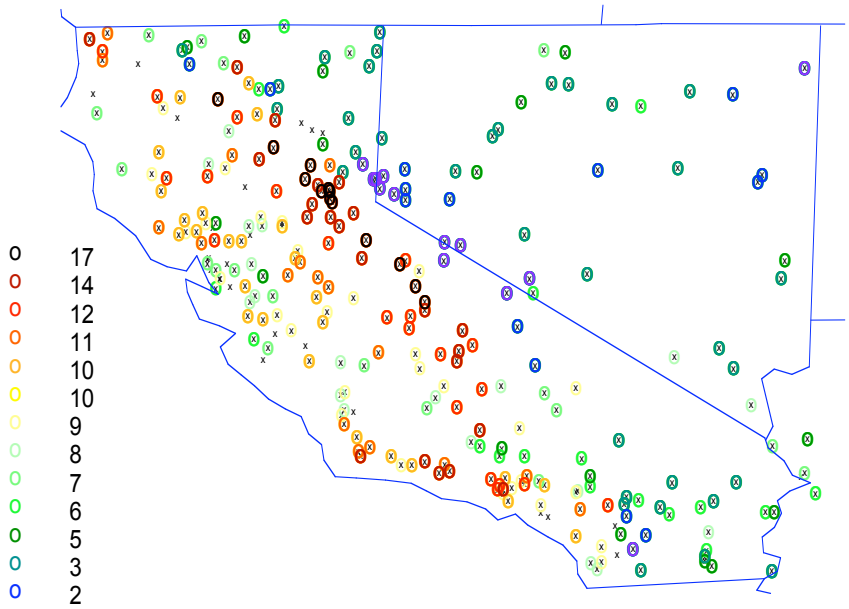


Model tends to produce precipitation of ***relatively correct intensity*** on the right days only on notable windward slopes.

This is perhaps amenable to statistical correction, but, we know, it is much to frequent…

How much “drizzle” to remove from model to correct modeled daily precipitation frequency

Threshold in mm that makes
modeled frequency = observed



Location-specific precipitation thresholds appear to be the first (and simplest) step to correct precipitation frequency in the model. This adjustment is large specifically where correction may be possible – areas of orographic enhancement.

Precipitation Summary

- Simple daily precipitation statistics and diagnostics in observation & model suggest:
  - Model gets it *right* on west and south-facing slopes where orographic uplift takes place
    - Model produces rain at the right time, but not the right amount AND much too frequently, even at this high spatial resolution!
    - Daily extremes are very poorly reproduced, but again, better on windward slopes
    - Interannual variability seems correct, suggesting that at least statistical correction may be possible
    - The first reasonable step to statistical correction in these regions is removal of large amounts of low-intensity precipitation
- Model failure over valleys and deserts needs to be scrutinized

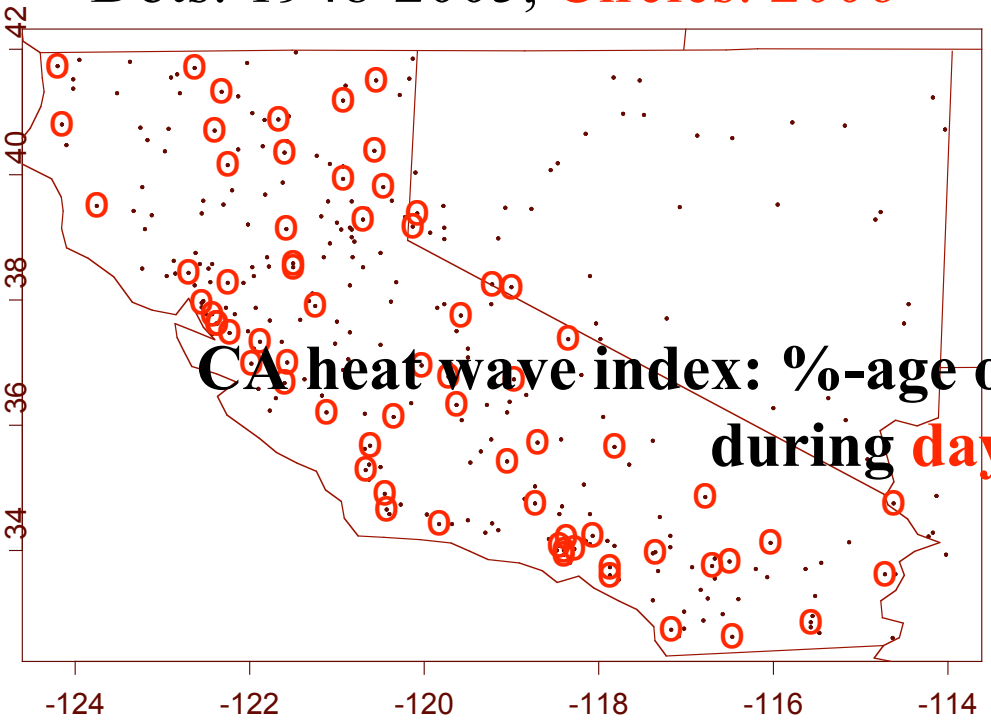
TEMPERATURE OUTLINE: HEAT WAVES

Observed and modeled heat wave activity

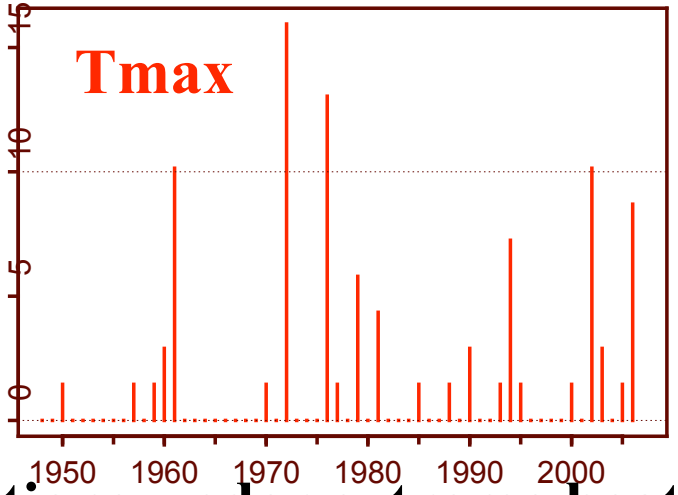
- Heat Wave Index: intensity, duration AND spatial extent, all related to impacts
- Trends
- Seasonal cycle of trends
- Regional origin or globally-induced?

California Heat Waves:
2006 and the climate record

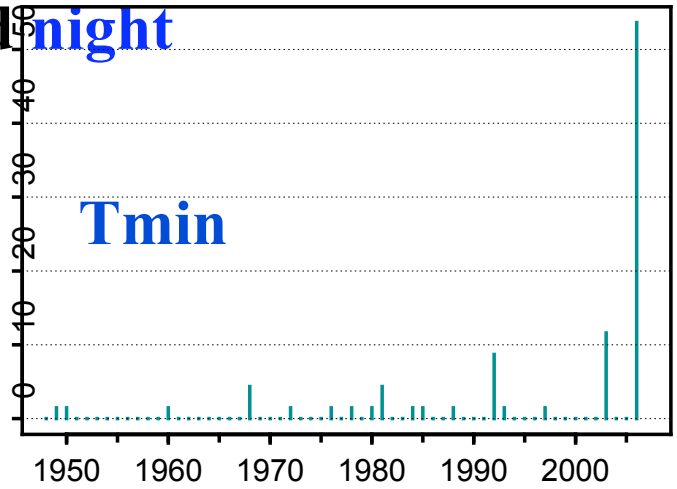
Daily NCDC station records.
Dots: 1948-2005, Circles: 2006



Current records through July 2006
at 69 stations



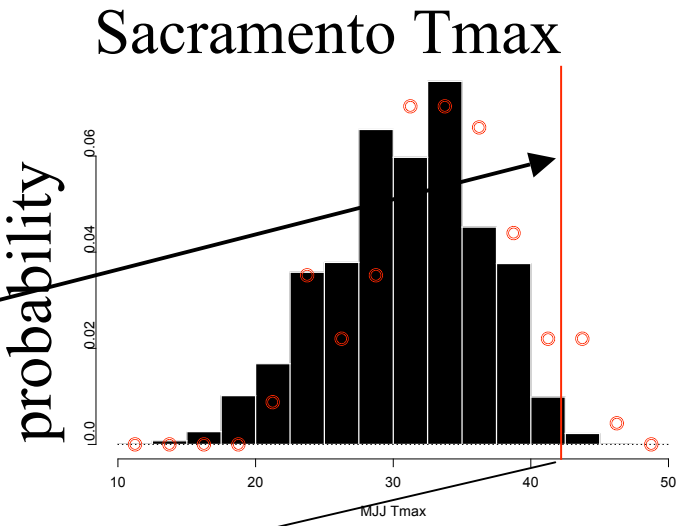
CA heat wave index: %-age of stations under extreme heat during day and night



Working definition of *extreme heat*

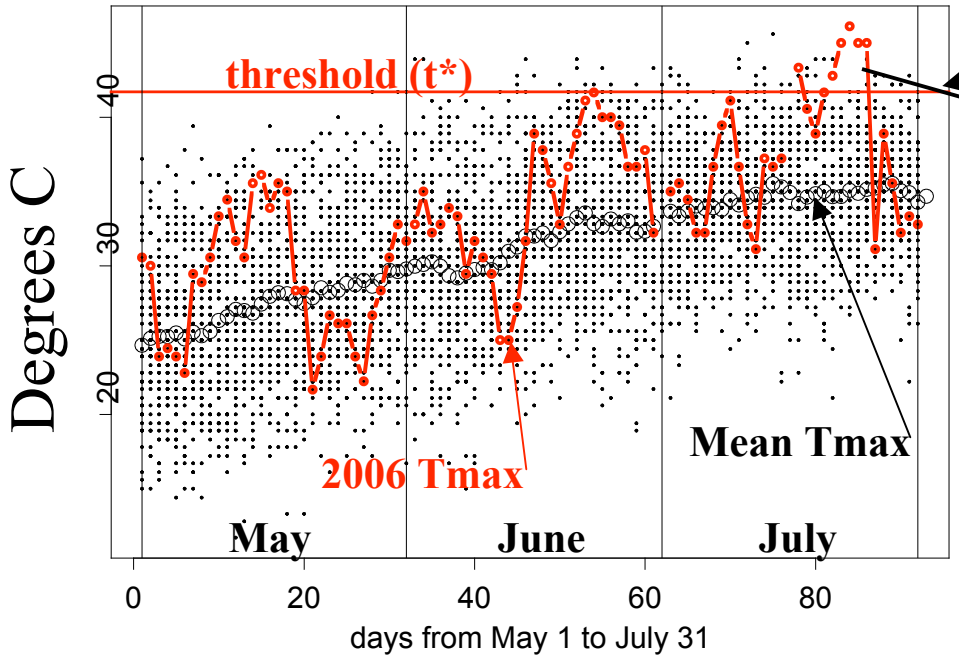
Tmax

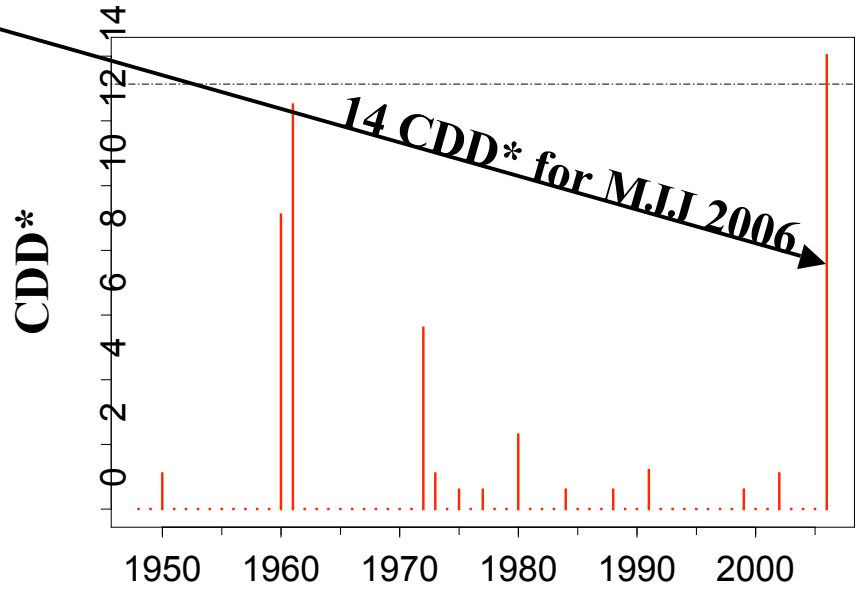
- **Locally extreme temperature exceeding a high percentile threshold t* (e.g. 99%-ile)**



Bars: 1948-2005 Tmax histogram, Circles: 2006 Tmax histogram, and Vertical line: all-yr 99th %-ile

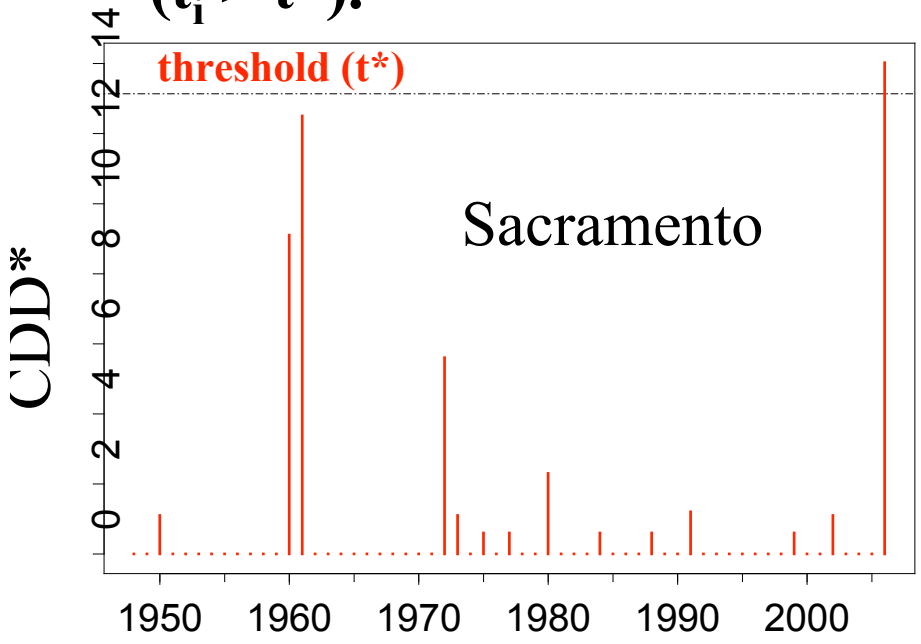
Time series view





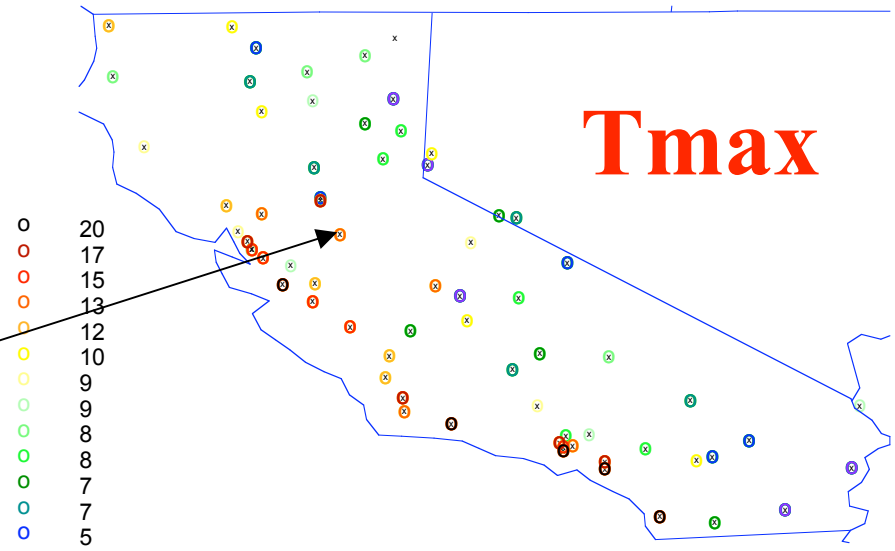
Working definition of *extreme heat*

- **Local heat wave magnitude and duration reflected in summing exceedances over threshold: $\sum(t_i - t^*)$, for all days (i) in a season such that $(t_i > t^*)$.**



Exceedances over threshold are summed up similar to CDD, but threshold is station-specific

99th %-ile of climatological exceedance sums



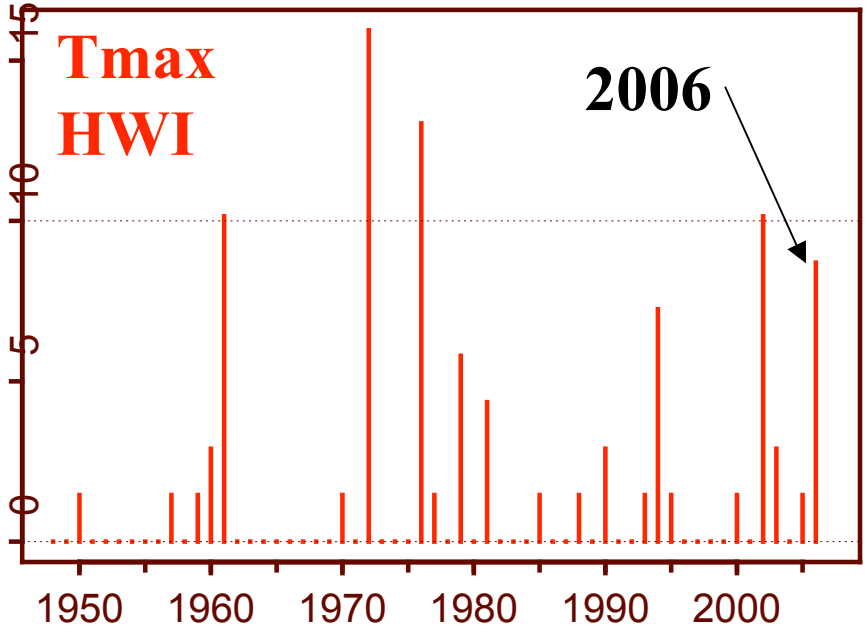
Exceedance sums are computed for each year at each station on the network that is weighted towards most populated areas

Working definition of *extreme heat*

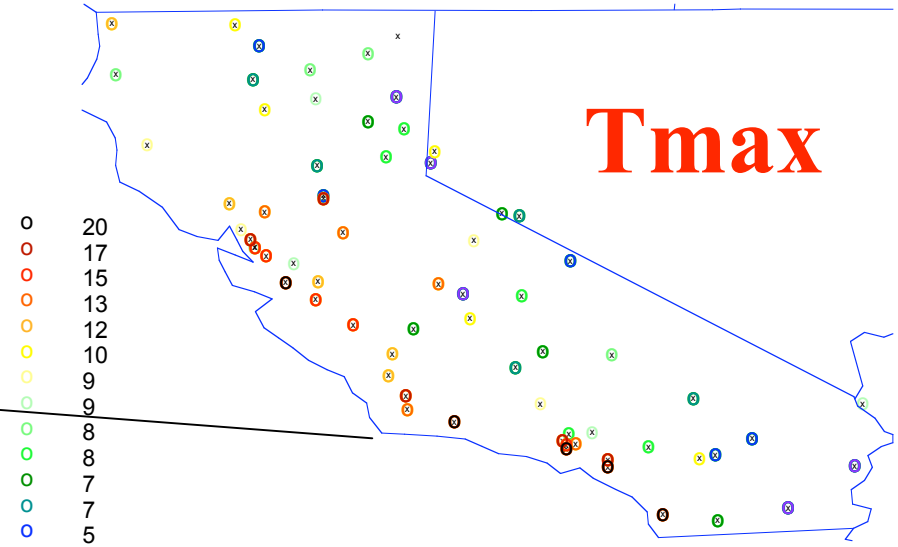
- **Spatial extent of locally extreme conditions**

2006 daytime heat was noteworthy, but not unprecedented

California Heat Wave Index

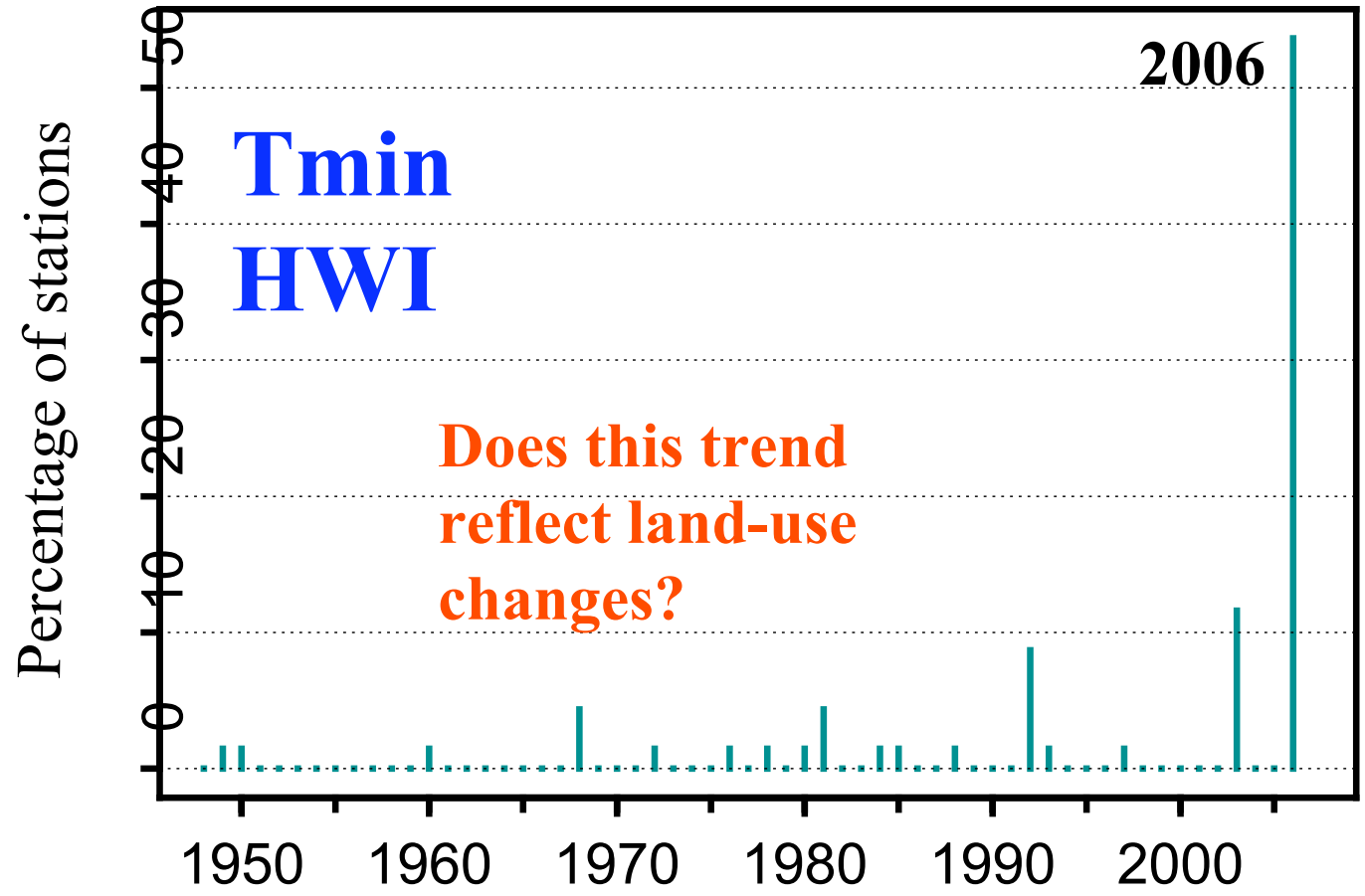


99th %-ile of climatological exceedance sums



For each MJJ on record, percentage of stations where exceedance sums (CDD*) exceed their local 99th %-ile becomes the regional heat wave index (HWI)

Now, if we do the same thing for Tmin, we get the California Nighttime Heat Wave Index

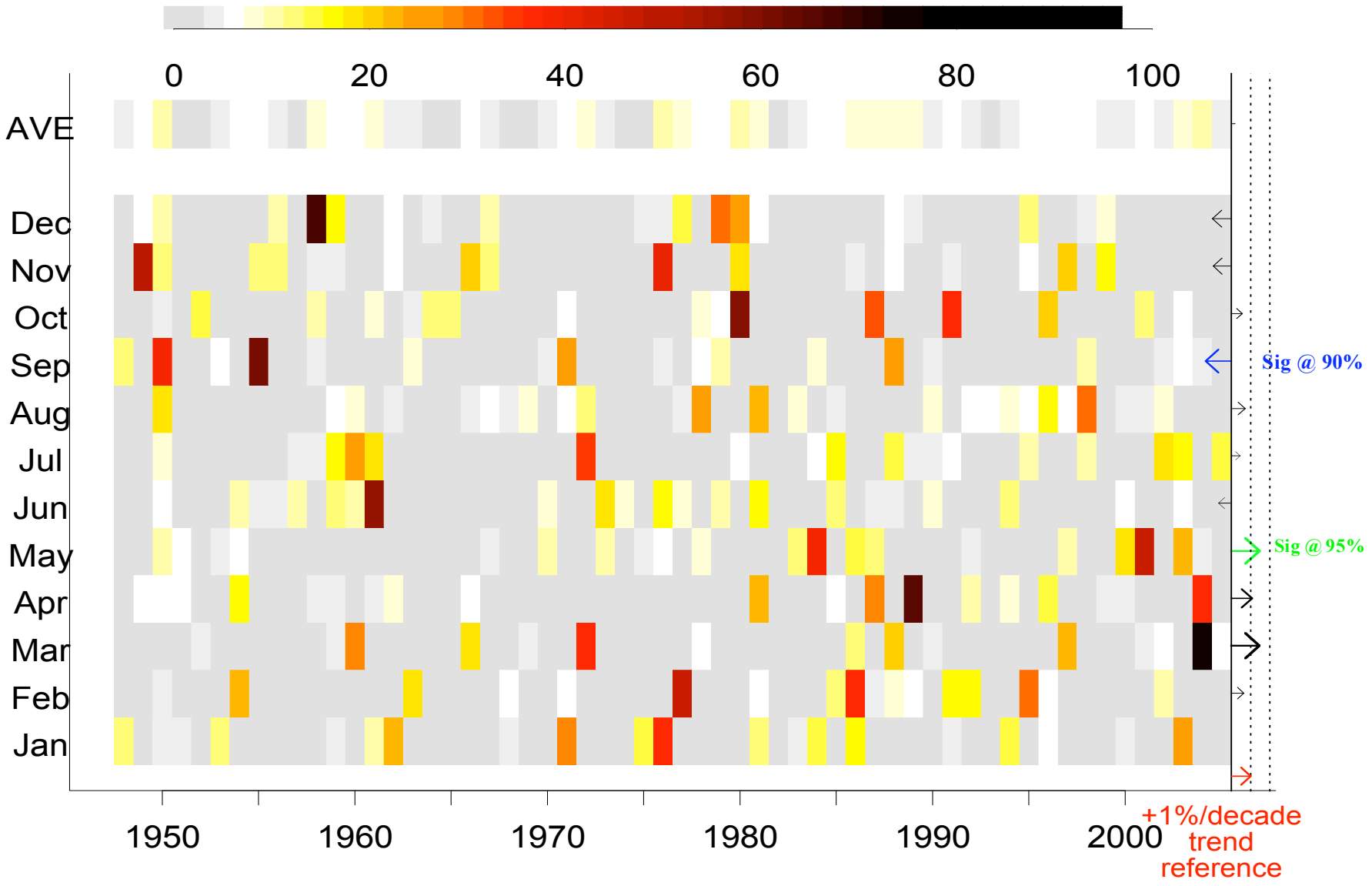


Seasonal Cycle of Trends in Pre-2006 (1948 – 2005) data…

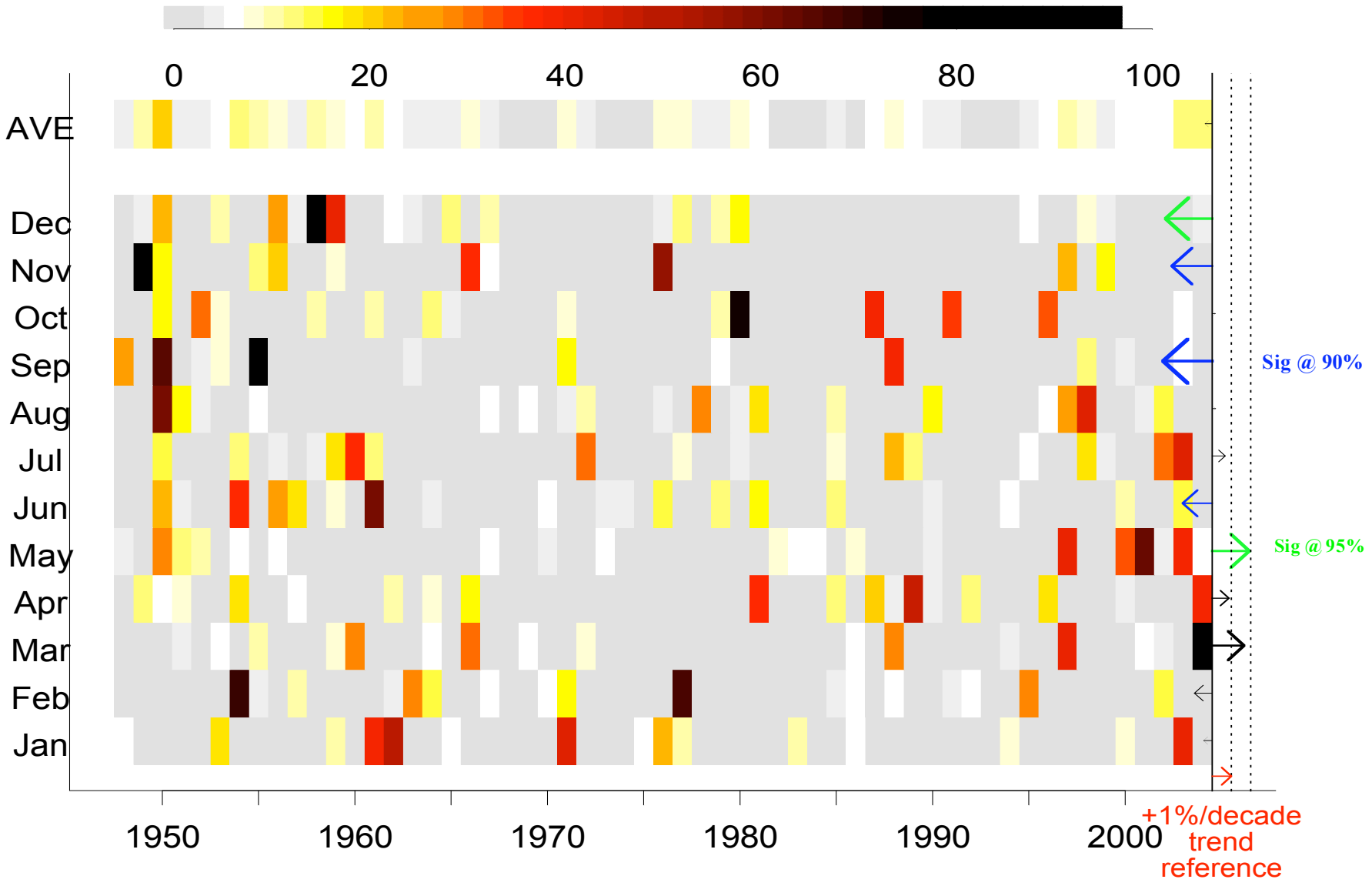
…at 286 stations, over California and Nevada,
and at corresponding grid cells …

…in CaRD10,
which does not know about land-use

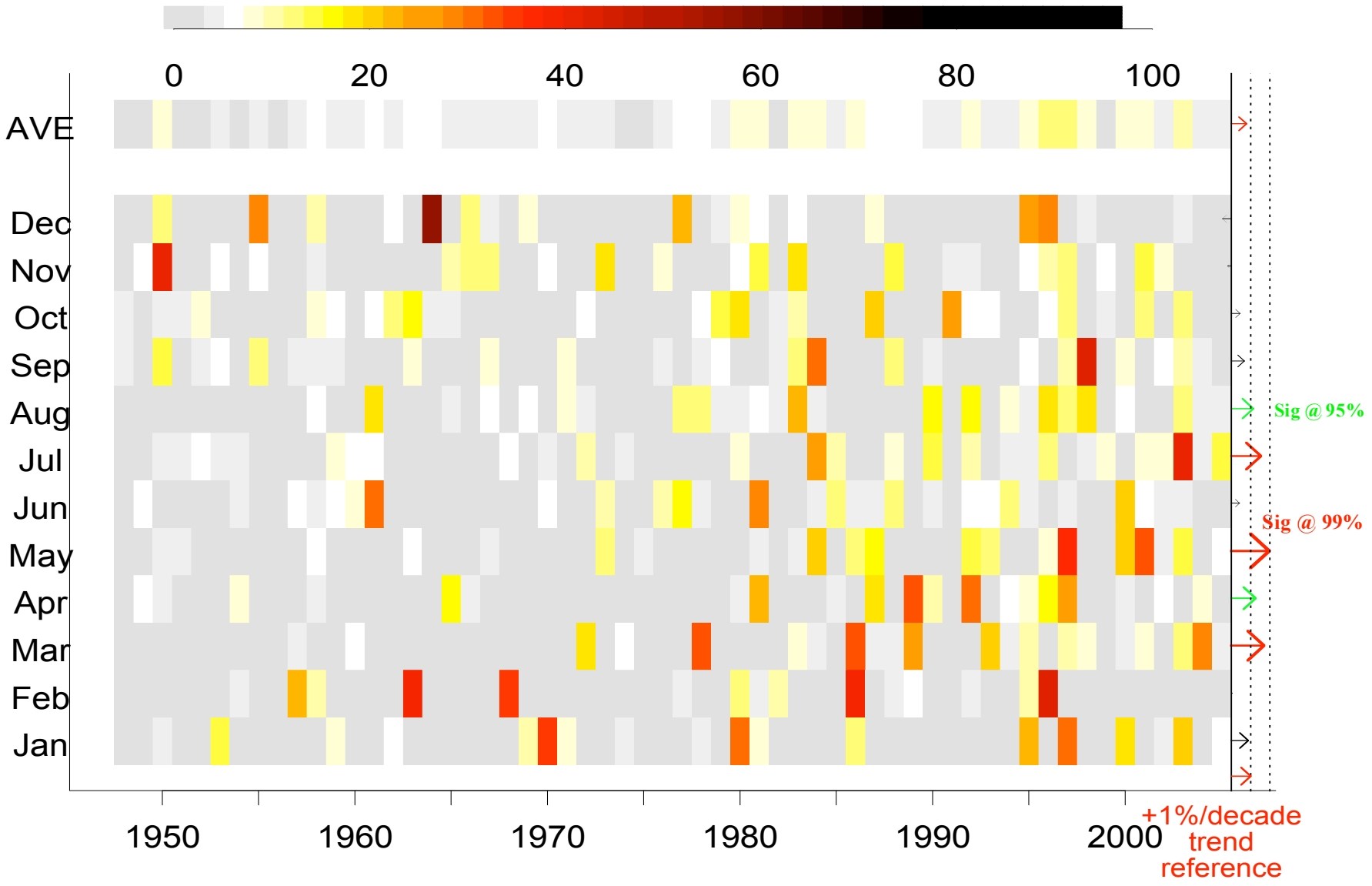
Observed Tmax HWI^{95}



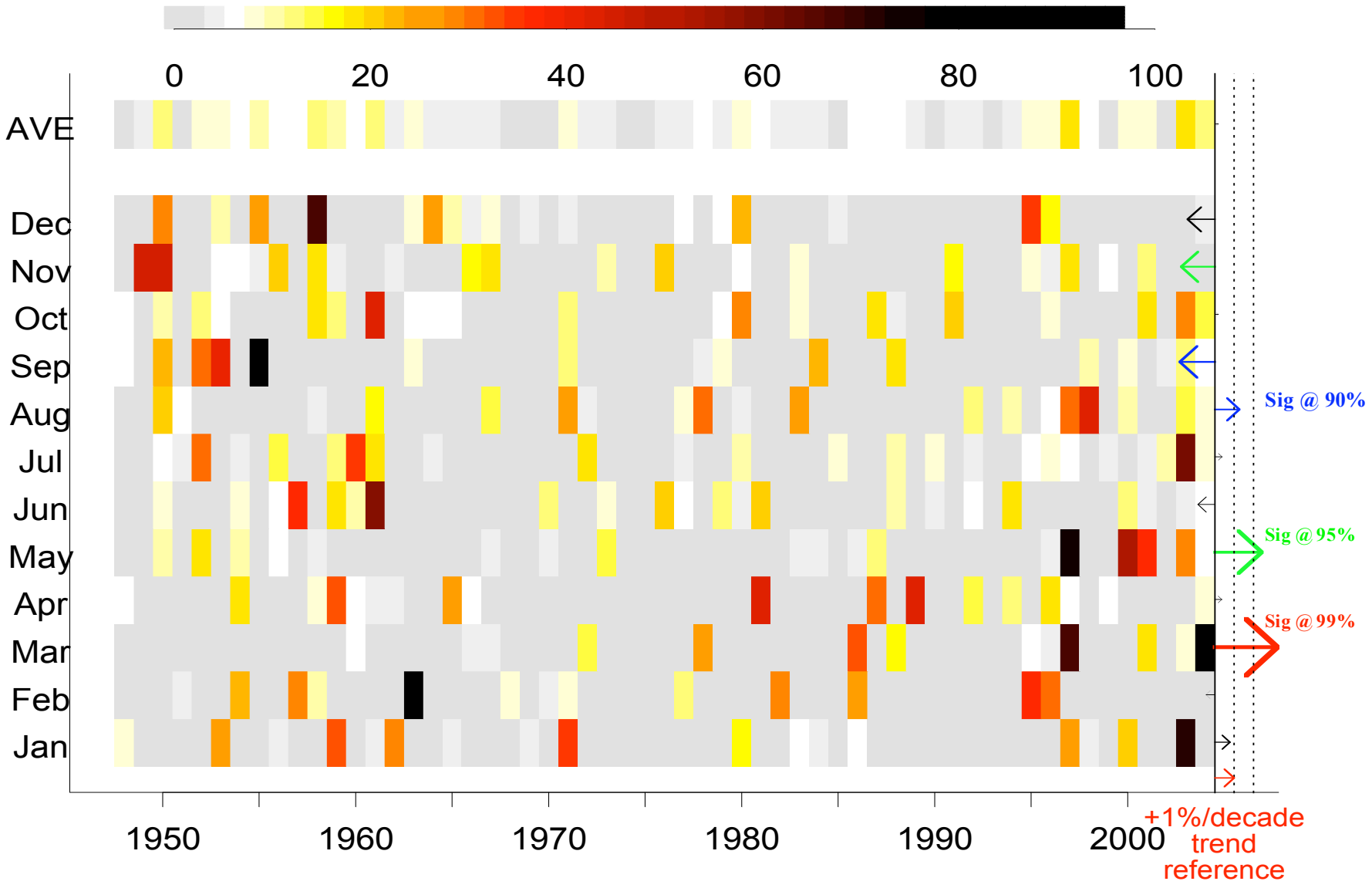
CaRD10 Tmax HWI^{95}



Observed Tmin HWI^{95}



CaRD10 Tmin HWI^{95}



Heat Wave Summary

Seasonal/monthly view of daily extremes in time and space:
individual seasons vs. multi-year climatology

- State-wide temperature extremes are on the rise, especially in Spring and Summertime and at Night
- Summer 2006 heat-wave activity was noteworthy during the day, unprecedented (in 59 years of quality observations) at night
- Regional reanalysis corroborates nighttime warming, strongly shows springtime trends, but much less so in the summertime
- Is this evidence of globally-induced springtime warming and more regionally-induced summertime trends?
- OR is Reanalysis germane to the task?